# HABITS OF THE LARVA OF BELLURA MELANOPYGA GROTE (LEPIDOPTERA).[1]

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Of the great host of *Lepidoptera*, only a few species have invaded the water and acquired aquatic stages in the life history. These few species have solved the problems of maintenance of aquatic life in exceedingly interesting ways, all presenting unique adaptations. The species on which this paper is based is aquatic in the larval stage and rivals the other species of similar habit in the character of its peculiar adaptations.

In 1881 Comstock ('81, pp. 147–149) published a short paper which included Grote's description of a new species, *Arzama melanopyga* (now *Bellura melanopyga*), and a very brief account of the larva of the same, presenting data on its unique habits and adaptations. This seems to be the only published account, the writer having searched in vain for other papers dealing with the habits of this larva. Comstock later ('88, p. 468) made mention of it and Grote ('89, p. 226) called attention to its habits and structures but in neither case were new data presented. The larval habits of a closely allied form, *Sphida obliqua* Wlk., which feeds on *Typha*, are better known and in a few respects resemble those of *Bellura melanopyga*. The following paper includes new data on the unusual habits of the larva and presents the detail of features merely mentioned by Comstock. *Bellura melanopyga* Grt. has been considered by some writers as a synonym of *Bellura gortynoides* Wlk. but the writer follows Hampson ('10, p. 260), who considers *melanopyga* a valid species.

The observations which form the basis of this paper were made by the writer while a member of the staff of instruction at the University of Michigan Biological Station at Douglas Lake, Michigan, during the three sessions of 1911–1913. The abundance of material and the opportunity to make observations at corresponding times during successive seasons made it possible

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to verify the data and to carry on some phases of the work which otherwise would have been impossible. The observations extended over the months of July and August of each of the three years. Larvæ of *Bellura melanopygà* began to appear during the first week of July and could be found until late in August. They feed on the leaves and burrow lengthwise into the petioles of the yellow waterlily, *Nymphæa americana* (Provancher) Miller and Standley ('12, p. 78). This lily occurs in considerable abundance in the beach pools and the protected bays of Douglas Lake. It also occurs in almost every sphagnum bog in the surrounding territory. This distribution seems to be dependent upon the fact that only at these places are attained the chief conditions which favor their growth, namely, protection from winds and waves, shallow water, and a more or less mucky bottom. *N. americana* was very abundant in one of the inlets (Bessey Creek) and the larvæ of *Bellura melanopyga* were correspondingly numerous, the infestation in 1912 being 90–95 per cent. The percentage of infestation in the beach pools and in the protected bays was much lower, not exceeding 25 per cent. This was probably due to the fact that Bessey Creek is much better protected from wind and waves, factors which are unfavorable to the very young larvæ. The lilies growing in the bogs of the surrounding region showed no signs of infestation.

## Feeding Habits.

The feeding habits of this larva were studied in considerable detail. These activities vary considerably according to the age of the larva. Two fairly well-defined periods can be recognized (1) a very early period, the *leaf-feeding period*, or the *mining period*, which lasts approximately throughout the first two stadia, and (2) the later period, the *petiole period*, which includes the remainder of the larval existence.

*The Leaf-Feeding or Mining Period.*—The eggs have not been observed but it is evident that they must of necessity be laid somewhere on the leaf since, as will be shown in a later discussion, the very young larvæ are not efficient swimmers and were often found in places where it would have been impossible for them to get had the eggs been laid elsewhere. Furthermore, at the

beginning of the season it was no uncommon thing to find twenty or more very young larvæ, 3–4 mm. in length, on a single leaf. The presence of so many very young larvæ on one leaf and the absence of larvæ from a contiguous leaf is taken as evidence that the eggs were laid somewhere about the infested leaf.

During the mining period the larva works on the upper side of the leaf. It usually cuts a somewhat circular hole, slightly larger than itself, through the upper epidermis and penetrates into the parenchyma, thus becoming a *miner*. There is no regularity in the shape of the mine. Sometimes it appears as a winding tunnel with a diameter about twice that of the larva; sometimes it is digitate in appearance; and sometimes it resembles a "blotch mine." The area included in each may vary to considerable extent. Holes through the epidermis other than the original entrance may occur anywhere throughout the length of the mine. Mines are easily detected on the surface of a leaf since they soon become whitish in appearance, due to the removal of the chlorophyll-bearing tissue. They may occur anywhere on the leaf. Leaves were sometimes found in which the mines appeared to extend either towards the midrib or towards the junction of the midrib with the petiole but an examination of a large number of infested leaves leads the writer to believe that no importance can be attached to these cases.

The initial entrance to a mine is usually surrounded by excrement and a small quantity of finely masticated leaf tissue. Microscopical examination shows that the latter is composed of the broken fragments of the epidermal cells and numbers of the peculiar *idioblasts* which are so common in the tissues of the yellow waterlily. Examination also shows that the fragments of the epidermal cells have not undergone digestion and furnishes evidence for believing that the larvæ never use the epidermal tissue as food but simply remove it with the mandibles. The excrement is greenish when first voided but gradually becomes lighter in color until finally all color is completely lost. It is voided in the form of small, somewhat oblong, uniform masses which tend to remain together, forming chains of varying lengths. Microscopical examination shows that it is composed of two kinds of elements: (1) idioblasts, which form as much as 60 per cent. of

the excrement and show no evidence of being affected by digestion, and (2) greenish, unorganized matter, which represents the remains of the digested parenchymal tissue.

Even in the very early stages the larvæ are active feeders. Larvæ, 5½ mm. long, constructed mines 14 mm. long in less than 20 hours. Larvæ, 7 mm. long, when transferred to new lily leaves completely buried themselves in four hours. Usually but one larva occupies a mine. Several instances were observed, however, in which two were occupying the same mine and in one heavily infested leaf eight larvæ of about the same size were found in a single, large mine. The formation of the mine is due primarily to the fact that the larva apparently uses only the parenchyma as food and must get under the epidermis in order to get it. However the mine has an indirect value since it furnishes a protection for the larva during the early and more helpless stages.

Several days after the mine has been formed the upper and lower epidermis bounding it begin to disintegrate, untimately leaving an ugly hole in the leaf and, in badly infested leaves, producing numerous perforations. The effect on the plant is evident. Not only is the leaf disfigured but in proportion to the number of holes present the leaf surface is also reduced. Many cases were observed in which the infestation was great enough to cause the death of the entire leaf.

In spite of the fact that in the Douglas Lake region a goodly number of other insects affect the yellow waterlily some of which also produce holes and burrows in the leaves, it is not difficult to identify the work of young *Bellura* caterpillars. Certain beetles (*Donacia*) make holes through the leaves in order to deposit eggs but these are distinguished by the circular shape of the holes, and by the rows of eggs or the remains of the eggs on the lower side while the holes made by the larvæ of *Bellura melanopyga* are usually irregular and bear no eggs on the lower margin. The larva of another beetle (*Galerucella nymphæa*) works on the upper side of the yellow waterlily leaf but instead of making mines it produces irregular trenches on the surface by eating away the epidermis, giving the surface a brownish, etched appearance.

*The Petiole Period.*—This period begins when the larva quits

the mining habit and begins to burrow lengthwise down the petiole. It is initiated when the larva locates either the midrib, or the junction of the leaf with the petiole, and from this time the feeding activities are confined almost entirely to the petiole. The latter is usually reached in one of two ways: (1) the larva burrows through the leaf substance or wanders on the surface until it reaches the midrib, whereupon it bores into it, tunneling towards the attachment of the petiole, or (2) the larva burrows or eats through the substance of the leaf or wanders on the surface until it reaches the attachment of the petiole where it then begins to excavate. At about this time the larva has attained such a size that mines can no longer be made but instead a broad slit in the leaf is produced. This slit (Figs. 3–5) is usually a trifle wider than the diameter of the larva producing it and almost invariably extends directly towards the midrib or its junction with the petiole. Sometimes a number of these slits are made before the larva constructs one which reaches into the substance of the midrib but all extend in the same general direction. If the midrib is reached first the larva bores lengthwise into it and towards the junction of the leaf with the petiole. Only very rarely were larvæ found boring in the opposite direction. The work in the midrib is merely preparatory to the work in the petiole, being only a means of getting into the upper end of the latter. It is not possible at present to account for the ability of the larva to recognize the position of the midrib or the petiole from any position on the surface of the leaf, and to distinguish between the apex of the midrib and the attachment of the petiole.

As will be shown later active dissemination of the larvæ begins at the initiation of the petiole period. Many instances were observed in which a larva had come to a new leaf and with surprising exactness had gone directly to the junction of leaf and petiole and had burrowed into it. Other similar instances were observed in which the larva on reaching a new leaf had cut a preliminary slit through the leaf leading directly to the top of the petiole. This ability to work directly from the periphery of a new leaf to the region of the petiole is especially marked in larvæ over 3 cm. in length. These facts were made apparent many times by field experiments in which larvæ 4 cm. in length

were removed from their burrows and placed on other leaves; also whenever it was necessary to restock the large tank, which served as the aquarium, by introducing larvæ from the field. In about 40 per cent. of these cases the larvæ bored into the petiole without any preliminary cutting of the leaf while others cut slits leading directly towards the attachment of the petiole. With the beginning of the petiole period comes the restriction of a single larva to each leaf.

*Length of the Burrows.*—The length of the burrow in the petiole varies according to the time it has been inhabited, and to some extent according to the size of the larva. Burrows were frequently two feet long and occasionally longer. Sometimes the burrow extended down to the rootstalk but no instance was observed in the field in which the burrow extended into it. There seems to be no reason why this should not occur since it will be shown later that the substance of the rootstalk can be used as food.

*Deserted Burrows.*—Burrows of various lengths were often found which had been constructed and then deserted without apparent cause. These burrows ultimately collapsed to some extent and became brownish on the inside. Usually they were inhabited by other aquatic animals, such as gyrinid larvæ, crustaceans (amphipods), chironomid larvæ, small aquatic coleoptera, and small leeches.

*Formation of New Burrows.*—In order to observe the initial steps in the production of a new burrow, larvæ 4½ cm. in length were removed from the petioles and placed in the aquarium on fresh, uninfested leaves. Some took to the leaves and began boring from the upper side of the leaf into the petiole while others attacked petioles which happened to be nearly horizontal and only partly under water. The larva began excavation by biting into the tissue until the mouth was full; then the head was withdrawn and the mass expelled at the margin of the hole. This was continued until the head was buried after which time the larva ate the tissue removed. Microscopical examination of the initial material deposited around the margin of the hole showed that it was merely pulverized leaf tissue.

*Other Points of Attack.*—Occasionally peduncles were found both in the field and in the aquarium which had been attacked.

In all cases the initial point of attack was at the top of the flower. Both opened and unopened flowers were affected. Floating rootstalks in the aquarium were always attacked and, if left for any length of time, were ultimately excavated through and through. This utilization of the substance of the rootstalk was not always caused by famine. A number of specimens were kept under conditions where rootstalk substance alone could be secured as food and apparently thrived on it. It thus appears that such materials may serve as food for these larvæ.

It sometimes happened that a fall in the level of the water caused portions of the long petioles to be bent above the surface of the water, or at least to lie on the surface. Whenever larvæ discovered these emergent petioles they attacked them, making an entrance through the side of the petiole.

*Excrement.*—In the field the best mark of recognition of the work of these larvæ is the heap of excrement which accumulates around the margin of the burrow on the upper side of the leaf. As would be expected the quantity depends upon the length of occupancy and the activity of the larva. In August it was a common thing to find hundred of leaves with conspicuous heaps of excreta around the hole on the upper surface.

The excrement is always deposited outside of the burrow regardless of the relation of its opening to the level of the water. Since the position of the larva is such that the posterior end is towards the leaf, the excrement is always deposited by thrusting the terminal somites out through the entrance of the burrow. That the level of the water has nothing to do with determining the place of deposition of excrement is shown by the following observations: (1) In floating, partially submerged rootstalks which had been tunneled by the larvæ it often happened that much of the upper part of the burrow contained no water but invariably all of the waste matter was deposited on the outside around the entrance. (2) Instances were observed where the entrance to the burrow was submerged for about an inch, due to a raising of the level of the water. The waste matter was always deposited at the entrance of the burrow and under water.

Microscopical examination of the excrement at all stages of the petiole period showed a composition similar to that described for

the leaf-feeding period. The percentage of idioblasts was large and they showed no indication of having been affected by the digestive process. The majority of the idioblasts were intact. Some showed signs of fragmentation, due to the initial action of the mandibles when the plant tissue was removed. Examination of the excrement also showed that, except for a short time when the larva is cutting away the epidermis and surrounding tissue in starting a new burrow, all of the material which is excavated passes through the alimentary canal of the larva and is subjected to the digestive process. Thus it is evident that the length of a burrow is a criterion of the amount of food material which has been taken from the plant. The larva is a voracious feeder, eating during both day and night, and large quantities of plant tissue are consumed.

*Effect on the Food Plant.*—The effect of the larva is such that infested plants are doomed. During the latter part of July and early August hundreds of leaves showed incisions converging towards the midrib and more especially towards the attachment of the petiole. Many leaves turned yellow and disintegrated, due to one or both of two causes: (1) eating in the region of the attachment of the petiole almost or entirely severed the connection of the leaf with the petiole; (2) the removal of the greater part of the substance of the petiole and the occasional eating through one side produced a more or less complete separation of the leaf from the rootstalk.

It thus appears that these larvæ produce havoc in the beds of *Nymphæa americana* and are a serious enemy since they not only disfigure the leaves but also actually cause the destruction of the same. They also destroy the flowers to some extent. In fact, of the goodly number of insects found on *N. americana* in the Douglas Lake region, the *Bellura* larvæ are usually the worst enemy. Fortunately the rootstalks seem to suffer but little from their attacks.

*Other Plants as Food.*—Observations and experiments showed that under normal conditions these larvæ use only the yellow waterlily as food. In the field none were found feeding on the white waterlily (*Castalia odorata*) notwithstanding the fact that in many cases *Nymphæa americana* and *Castalia odorata* occurred

in the same locality, frequently intermingling and contiguous. In the region studied *Castalia odorata* is surprisingly exempt from insect attacks. Beutenmüller ('02, p. 440) states that, in the vicinity of New York City, the caterpillar of *Bellura melanopyga* "bores in the leaf-stalks of the common white pond lily and yellow pond lily." Assuming that the "common white pond lily" referred to above is *Castalia odorata*, it appears that the larva may work normally on it in certain other localities. However, the evidence collected in the Douglas Lake region is entirely contradictory.

Experiments were carried on at the laboratory with the view of determining whether or not these larvæ could be forced to use other food. The following are typical experiments and results: *Experiment 1.* Two larvæ, each 6 mm. in length, were transferred to a watch glass containing a piece of leaf of the white waterlily (*Castalia odorata*) which was kept moist. During the first eighteen hours the larvæ wandered restlessly about, then finally began working on the white waterlily leaf and at the end of four hours one had completely buried itself and the other was making similar headway. Fresh pieces of the white waterlily leaf were used to replace the eaten ones from time to time and these larvæ were kept thus for twelve days. At the end of that time both were alive, apparently in healthy condition and one ecdysis had occurred. The results show that it is possible for the larvæ to use the white waterlily as food when forced to do so by the absence of the normal food. *Experiment 2.* Both yellow and white waterlilies were placed in the same aquarium which was stocked with several larvæ, 4 cm. in length. The larvæ attacked the yellow waterlilies and worked on them continuously. Ultimately the food plants were consumed and a famine was allowed to occur. After a lapse of several hours only one case was observed where larvæ were attempting to tunnel into the petiole of one of the white waterlilies and it was finally abandoned, the larvæ wandering restlessly about the aquarium. *Experiment 3.* Larvæ were placed in covered dishes containing *Potamogeton natans* and *Sagittaria* sp., plants which occurred in abundance in the same habitat with the waterlilies, and were left thus for several days. The tissues of these plants were invariably and constantly refused.

## Respiration.

One of the problems which confront an insect possessing an aquatic stage is that of securing the requisite amount of oxygen. Those few genera of *Lepidoptera* which are unique in having aquatic larvæ have solved the problem in one of two ways: (1) by the utilization of the dissolved oxygen, either by means of gills or through cutaneous respiration, or (2) by making periodic trips to the surface in order to secure the oxygen from the air. Each of these adaptations calls for distinctly differentiated structures and each is accompanied by interesting habits and activities. *Bellura melanopyga* has solved the oxygen problem by a peculiar development of the spiracles and by making *periodic trips to the surface.* A careful study has been made of this adaptation and the results will be given in some detail.

*Respiratory Apparatus.*—Paired spiracles are present on I, IV, V, VI, VII, VIII, IX, X, and XI. All, exclusive of the pair on XI, are similar in size, are elliptical in shape, are lateral in position, and have the long axis vertical. Somites I–X are similar but XI–XIII form the chief structural differentiation accompanying this aquatic habit. XII is very short, being only about one-fourth as long as XI, and its dorsal surface is depressed considerably below the corresponding surface of XI. The dorsal, posterior margin of XI bears two large, elliptical spiracles, one on each side of the median line. They are placed obliquely, the long axis being inclined about forty-five degrees from the vertical. They are at the posterior termini of the lateral, longitudinal tracheal trunks, opening directly into them. All other spiracles have short branches leading into the longitudinal trunks. Each of the terminal spiracles on XI opens into a somewhat enlarged region of its respective longitudinal trachea which probably serves as a reservoir for the supply of air which is carried below the surface by the larva on its downward trips. XIII is somewhat larger than XII and forms the cauda. Its dorsum is on the same level with that of XII and the lateral margins converge caudad.

*The Leaf-Feeding Period.*—During the leaf-feeding period respiration is carried on in the same way as in terrestrial lepidopterous larvæ. Each larva is working in a mine in the leaf but

the entrance hole and other openings which usually occur are sufficient to provide the necessary air.

*The Petiole Period.*—When the larva deserts the leaf and becomes a borer in the petiole new conditions are encountered and new provisions must be made. The leaves of *Nymphæa americana* are never normally held above the surface of the water by the petiole as in the case of *N. advena* but the emergent leaves float on the surface. This means that the burrow in the petiole is filled with water and that the larva is submerged. When the length of the burrow increases to such an extent that it is longer than the body of the larva which is making it, the latter is compelled to resort to other means of getting air. To do this the larva makes *periodic trips* to the surface where the fresh air is drawn into the tracheal system in sufficient quantity to allow a sojourn of several minutes under water at the bottom of the burrow.

As stated previously, the larva lies in the petiole with the posterior end towards the top of the burrow. This position eliminates the necessity for the larva to come out of the burrow when taking air, and to turn around when starting on its trip to the top. When at the bottom of the burrow the larva feeds (or in some cases merely rests) until the need for air stimulates it to return to the surface. Then it *backs up* to the top of the burrow, stopping when the large pair of spiracles on the posterior margin of XI is just pushed above the surface film. It remains in that position until sufficient air has been taken into the trachea to permit a return to the bottom of the burrow again. This alternate sequence of feeding and breathing goes on continuously so long as the larva remains in the burrow. In this form of respiration it appears that the other spiracles are not needed since only the posterior pair is pushed above water.

*Frequency of Trips to the Surface.*—A number of observations were made on various larvæ in order to determine what is the normal period of time spent under the water and likewise the normal period spent at the top. The records were made by means of a stop-watch and the observations on each larva were carried on long enough to secure data showing the range of variation in each case. The average of 128 observations involv-

ing 13 different larvæ, 4–6 cm. long, showed that the interval spent below the water was 2 minutes and 57 seconds, and the time interval spent at the top was 1 minute and 21 seconds. The maximum period of time voluntarily spent below was 13 minutes while the minimum was 20 seconds. The maximum period at the top was 6 minutes and 40 seconds, and the minimum was 5 seconds. Comstock ('81, p. 148) states that he observed larvæ of this species remain under water for a half hour but in the large number of observations made in this connection none remained below over 13 minutes.

In connection with the observations on the frequency of trips to the surface, the question arose as to whether there was any correlation between the length of the burrow and the length of time between appearances at the top. In order to determine this point observations were made on a number of larvæ from day to day as they increased the length of their burrows. Results show that the length of the burrow does not in any way determine the time spent below the water. In fact, they show that the intervals are approximately the same when the burrow is but 6 cm. long as when it is over 20 cm. in length. From an examination of all results secured in connection with this study, the writer is convinced that the length of the periods spent under water is purely a matter of supply and demand of oxygen, that it is dependent upon the amount of air which the larva draws into the trachea when at the top and the activity of the larva in the process of feeding at the bottom of the burrow.

*Resistance to the Lack of Oxygen.*—Experiments were carried on to determine how long larvæ can live under water, when forced to do so, without renewal of the air supply. The entrances to the burrows were plugged in such a way that the inmates could not get air at the top, and the time recorded. These petioles were visited at regular intervals and the condition of the larvæ noted. Larvæ were also placed in tubes of water which were corked so that no air spaces were left at the top, and the condition of the specimens carefully observed. These experiments showed that death usually occurred after an interval of about two hours. After 15 or 20 minutes of continued submergence larvæ began to show the first signs of uneasiness and evidences of weakness began to appear at the end of an hour.

In this connection another set of experiments was carried on in which the infested lily leaves were staked down under water to a depth of six or seven inches and the behavior of the larvæ under these new conditions noted. Each larva came to the top of the burrow and gradually pushed the posterior end out through the entrance, continually searching in a random fashion for the surface film. Ultimately it loosened its hold, came to the surface, and swam about until it came to another lily leaf. In some cases larvæ lived for 45 minutes under water before they would release the hold and come to the top.

*Expired Air.*—After a larva has been at the bottom of a burrow for a brief interval one or two bubbles usually rise to the top. This happens commonly at the end of the period below and just before the beginning of the trip to the top. These bubbles probably represent, in part at least, expired air which is expelled from the tracheæ.

*The Breathing Position.*—Except when the larva voluntarily leaves the burrow, it only tips the surface with the posterior end when taking air. Normally only the dorsal surface of XII and XIII and just enough of the posterior margin of XI to include the large dorsal spiracles is above the surface film, the other portions of the body remaining under water. When the larva comes to rest at the breathing position the terminal spiracles pull down the surface film, forming a small conical depression. When in this position the larva is very sensitive to surface disturbances and responds quickly to them by retreating into the burrow. Thus in making observations on the breathing activities it was very necessary to avoid making even the smallest ripples or swells. Very tiny jars on the leaf produced the same response. The alighting of a small insect on the same lily leaf was sufficient to cause the larva to dodge below. It is very probable that this response is responsible for the avoidance of many attacks by predaceous enemies.

*Breathing Movements.*—If a larva in the breathing position be watched carefully it will be noted that certain rhythmic movements are performed. These movements occur at intervals of from two to three seconds and appear to consist of an alternate contraction and expansion of the exposed region.

*Extrusion of Excrement.*—The voiding of excrement occurs in connection with the respiratory trips to the surface but since these trips are the direct effect of the demand for oxygen the extrusion of wastes is only an accompanying feature. The ratio of the number of respiratory trips to the number of extrusions is variable, depending upon the feeding activity of the larva. The following records will serve to illustrate the variation:

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| Larva no. 1 | 2 extrusions in 14 trips to surface. |
| Larva no. 2 | 1 extrusion in 11 trips to surface. |
| Larva no. 7 | 1 extrusion in 41 trips to surface. |

## Locomotion.

Dissemination is accomplished in three distinct ways, viz., swimming, floating, and crawling.

*Swimming.*—The larva usually swims on the surface although when forced to do so it can swim to a limited extent below the surface. The specific gravity of the larva in all stages is very slightly less than that of water, thus making it easy to remain at the surface. Furthermore, the larva at all stages has an oily surface which prevents a "wetting" of the exterior and constitutes another means of remaining on the surface. This form of locomotion is accomplished by means of a series of rather vigorous horizontal undulations in the execution of which the whole body takes a part. The caterpillar lies in a trough in the surface which partially surrounds it and is propelled by the characteristic sinuous movements. The efficiency of this kind of locomotion varies with the age of the larva and the amount of disturbance of the surface of the water. Very young larvæ do not progress very rapidly but the full-grown ones are efficient swimmers, showing noteworthy speed and endurance. Larvæ, 4 cm. in length, were removed from their burrows and placed in the open water in a protected bay where the surface was perfectly quiet. They immediately began to swim and records were made of the rate of progression. In one instance a larva made a continuous swim of 250 feet in 19 minutes and at the end of the journey showed little or no signs of weakness. A number of similar records were made with similar results. Ripples, diminutive waves, and currents interfere seriously with this form of loco-

motion, even with full-grown larvæ, and little or no headway can be made against them. Owing to the fact that the situations which are favorable for the growth of their food plant are characterized by quiet water, the interference with dissemination due to surface disturbances is not great.

The advantage to the larva of this surface swimming is obvious. It must have free air and many of the journeys which it makes require a longer time than it can remain under water but the ability to swim on the surface makes it possible to secure air with ease.

When larvæ are placed beneath the surface of the water and released they immediately orient themselves in such a way that the head is towards the surface and, by means of the undulatory movements of the body, swim diagonally upward, continuing the effort until the surface is reached. Swimming below the surface is much less efficient than on the surface but it is usually effectual in assisting the larva in getting back to the top. When submerged they appear to lack the ability to do effective climbing on stems and other objects with which they come in contact.

When swimming on the surface the larva shows a strong tendency to climb upon any object which comes in its way and in case the object is immovable, has a smooth upper surface, is above the surface of the water, and broad enough to support the greater part of the length of the body, it will usually come to rest for a time. In cases where the object is very limited in size, as for example a stick, twig, or stem, the larva usually climbs over it and continues the journey. Larvæ may desert the leaves and voluntarily take to the water. When once in the water the swimming movements are usually kept up continuously until another flat, emergent object is reached. When a larva deserts one lily leaf the search for another food plant is entirely a random one and the contact with another leaf seems to be purely accidental. It merely keeps on swimming until it happens to choose a course which leads to a leaf. The larva apparently has no means of recognizing the presence of a food plant except when in contact with it. The writer observed instances where larvæ swam aimlessly about for a half hour without finding a food plant, having passed several times within a centimeter of a lily leaf.

The larvæ under observation showed a definite response to currents of low rapidity. When placed in the open water of a stream having a current of 10 feet per minute they almost invariably swam down stream. This accounts for the prevalence, at the mouth of Bessey Creek, of infested leaves showing attack only at the junction of the petiole with the leaf—an indication of the work of the older larvæ.

*Floating.*—Instances were observed where larvæ were transported from place to place by floating down stream on detached leaves and other floating objects. Occasionally a swimming larva became passive and, since it remained on the surface, it was carried along with the current.

*Crawling.*—Change of position on the leaf is accomplished by crawling and, in case lily leaves are contiguous, means is thus provided for the passage from one leaf to another. When in search of a new leaf the larva usually explores the periphery of the leaf, taking to the water and swimming only when it is not possible to reach another leaf from the supporting one. The explorations at the edge of the leaf consist in projecting one-third to one-half of the body over the edge and swinging it about as if seeking another support. If nothing is within reach, the body is withdrawn and the same performance repeated at another place. If, however, an object is within reach the larva immediately crawls upon it.

In cases where larvæ were deserting the old leaves it was not always possible to account for the departure. The two most common incentives apparently were (1) the presence of other larvæ on the same leaf, since only one larva can occupy the burrow in the petiole, and (2) the deterioration of the lily leaf and petiole which results in an unfitting of the plant for the larva.

## Enemies.

These larvæ were eagerly snapped up by sunfish whenever there was opportunity. They were comparatively safe in the burrows but whenever they left the lily leaves and swam in open water the mortality was often high. Specimens removed from the petioles and thrown out into open water were soon discovered and captured. The undulatory swimming motion appeared to be

fatally effectual in attracting the attention of fish. A number of instances were observed in which specimens thrown out were not molested so long as they remained motionless but unfortunately for them they remain quiet for only short intervals, often not exceeding 60 seconds, and soon after swimming began were snapped up. Fish of all sizes appeared to feed upon them. The larger fish always secured the prey at the first dash but small fish were observed to make three or four attempts before the full-grown larva could be secured.

The large water strider (*Gerris* sp.), common in the Douglas Lake region, was observed to attack the larvæ when they happened to be on the surface of the leaves. The ultimate effects of such an attack were not observed since in every case the larva attacked happened to be under observation for other data and the striders were driven off.

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April 23, 1914.

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## EXPLANATION OF PLATE.

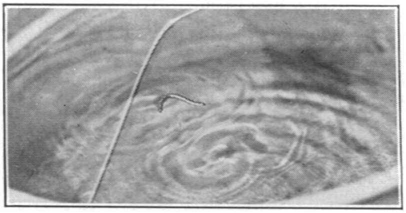
FIG. 1. Photograph of a nearly full-grown larva of *Bellura melanopyga* swimming on the surface of the water in the aquarium. The undulations of the body in performing the swimming movements are evident.

FIG. 2. Photograph of the same larva taken a few seconds later.

FIG. 3. Leaf of *Nymphæa americana* showing the character of the work of approximately mature larvæ. The radiating slits represent the work of the larvæ preliminary to the excavation of the petiole. Note the severe injury to the leaf in the region of the petiole. Leaves are sometimes almost completely severed from the petiole in this way.

FIG. 4. Leaves of *Nymphæa americana* showing the work of half- to full-grown larvæ and the characteristic form of the injury.

FIG. 5. Leaves of *Nymphæa americana* infested by half- to full-grown larvæ. The leaf near the center of the figure shows the absence of preliminary cutting in the form of radiating slits. Note on the same leaf the heap of excrement about the hole at the junction of leaf and petiole. This hole is the entrance to the burrow in the petiole.



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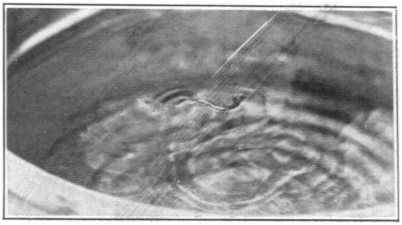

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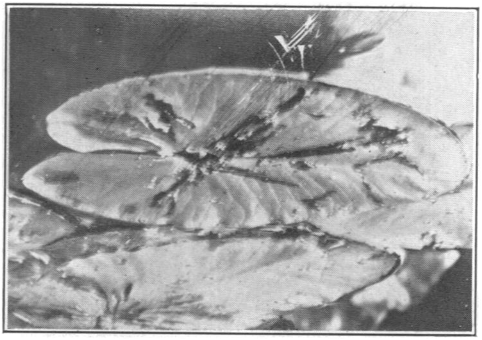

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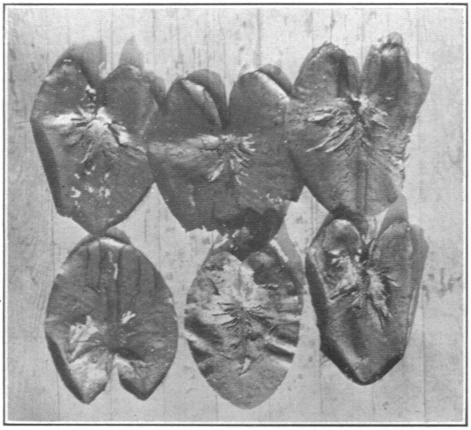

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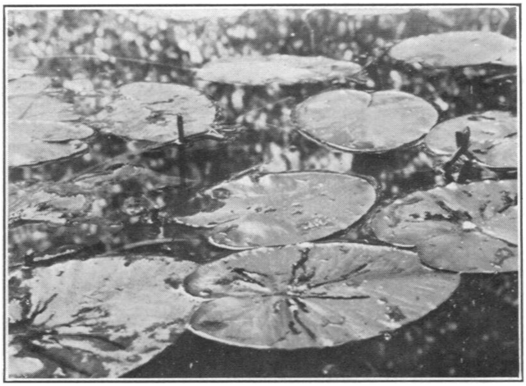

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